PRELIMINARY PLANNING ALTERNATIVES

FOR

SOLVING AGRICULTURAL DRAINAGE AND DRAINAGE-RELATED PROBLEMS IN THE SAN JOAQUIN VALLEY

EXECUTIVE SUMMARY

August 1989

San Joaquin Valley Drainage Program

U.S. DEPARTMENT OF THE INTERIOR

Bureau of Reclamation
Fish and Wildlife Service
Geological Survey

CALIFORNIA RESOURCES AGENCY

Department of Fish and Game
Department of Water Resources

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2800 Cottage Way, Room W-2143
Sacramento, California 95825-1898

PREFACE

Current agricultural drainage conditions on the west side of the San Joaquin Valley present two basic problems: (1) Salt buildup and waterlogging of irrigated lands due to a high ground-water table, which adversely affects crops and productivity, and (2) toxic or potentially toxic trace elements in the shallow ground water, which when drained and discharged to streams, ponds, or wetlands, can adversely affect fish and wildlife.

The severity of the toxics problem has been known only a relatively short time. It came into focus about 6 years ago with the discovery of migratory-bird deaths and deformities linked to high levels of selenium in agricultural drainage water at Kesterson Reservoir. Concentrations of drainage-water contaminants and rates of deformities higher than those found at Kesterson are now being found associated with evaporation ponds in the Tulare Basin, in the southern part of the valley.

Drainage problems affecting agriculture are almost as old as irrigated agriculture in the valley. As early as the 1890's, some cultivated lands were forced out of production because of salt and drainage problems. Despite the long history of drainage problems, efforts to solve them have been fragmented and remain uncompleted. Many people involved in drainage issues believe that a sustainable, long-term solution to the problems affecting agriculture will have to be accomplished in several phases. The first, and probably most critical, phase involves solving the problem of toxicants such as selenium.

Understanding of drainage conditions and problems in the valley has been greatly improved in the last few years, and critical evaluation of potential measures for solving those problems is required. Some 70 individual options that potentially could contribute to management of the problems have been identified by the Drainage Program, including measures that are currently being practiced as well as those that are as yet unproven and still under investigation. This report presents preliminary planning alternatives utilizing several of these options, all of which represent currently available technologies. The alternatives represent short-term or interim fixes to address problems expected to exist in the year 2000; in most cases, however, the measures and associated benefits would extend for many years. The Drainage Program is in the process of developing additional alternatives to meet both short- and long-term needs.

In 1987, the Drainage Program narrowed its focus on planning alternatives to measures that could be taken to address the agricultural drainage and related problems within the San Joaquin Valley itself. This decision reflected the need to control conditions and manage problems as close to their source as possible, and to help ensure that areas outside the valley are not adversely affected by the problems or measures to solve them.

We believe that the problem of toxicants such as selenium can be managed within the valley, particularly if over the next few years the cost of drainage-water treatment can be significantly reduced. It is equally clear, however, that because of its sheer magnitude the salt problem cannot be solved, over the long term, solely in the valley. At present, more than

3 million tons of salt accumulates each year in the shallow ground water, soils, and valley evaporation ponds. The long-term effect of not managing the salt-accumulation problem--to let present trends continue without implementation of a comprehensive management plan--will be to severely limit the uses and value of valley lands and ground water. As gains are made in managing drainage-water toxicants in the valley, the annual salt buildup should be reduced and opportunities will be greater for developing long-term solutions to the salt problem.

We look forward to your review of planning alternatives and to your participation in developing the best possible solutions to valley drainage and drainage-related problems.

Ed Imhoff

Edgar A. Imhoff, Manager
San Joaquin Valley Drainage Program

EXECUTIVE SUMMARY

The lack of adequate drainage has long been recognized as a serious problem for irrigated agriculture in the western and southern San Joaquin Valley. For that reason, the Federal and State projects importing irrigation water to that area included plans for a master drainage canal leading to the Sacramento-San Joaquin Delta.

By 1975, 85 miles of the San Luis Drain, 120 miles of collector drains, and the first phase of Kesterson Regulating Reservoir were completed and began receiving subsurface drainage water from lands in the Federal service area.

In 1983, with the discovery of migratory-bird deaths and deformities linked to high selenium levels in agricultural drainage water at Kesterson Reservoir, it became clear that the valley's drainage problem involved not only agriculture, but also fish and wildlife resources, water quality, and possibly public health.

In mid-1984, five State and Federal agencies formed the San Joaquin Valley Drainage Program (SJVDP) to investigate drainage problems and identify possible solutions. In 1987, the SJVDP narrowed its focus on planning alternatives to measures that could be taken to address drainage and related problems within the valley itself. (Accordingly, the concept of a master drain leading out of the valley is not within the scope of this Program.)

This is a summary of the SJVDP's interim report on alternatives for solving valley drainage problems. The final report, due by October 1990, will include additional material based on public reviews and on research now nearing completion.

THE STUDY AREA

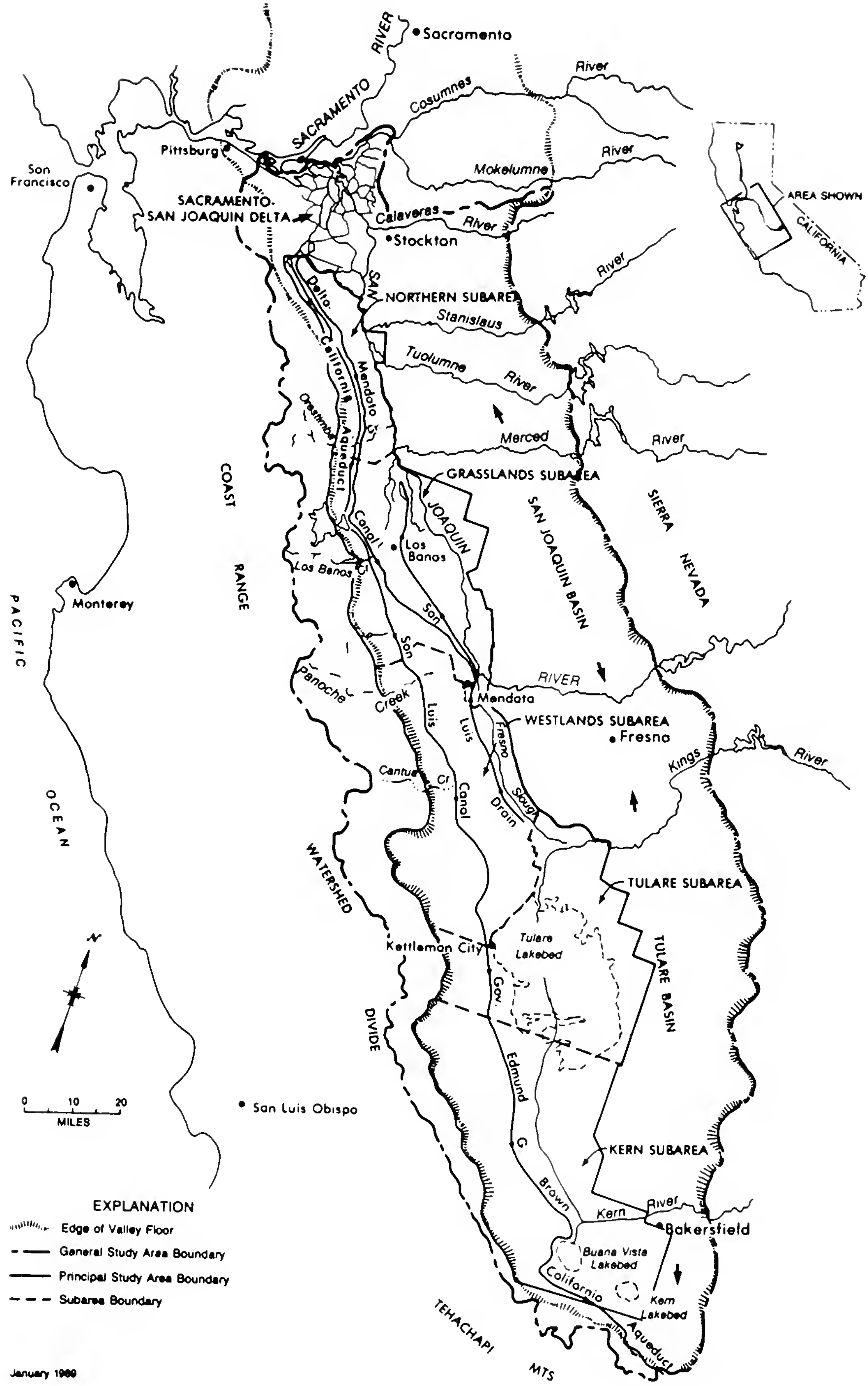
The SJVDP study area includes the entire valley but concentrates on the western half (the west side), where most of the drainage problems originate. The west side is divided into five subareas--Northern, Grasslands, Westlands, Tulare, and Kern. (See Figure 1.)

Certain geographical characteristics of the study area should be kept in mind:

- The area is hot and dry, with average annual rainfall ranging from 5 inches in the south to 10 inches in the north. Irrigation is required for most agricultural crops.

- The area contains two major drainage basins. To the north, the Northern and Grasslands Subareas and part of the Westlands Subarea drain naturally into the San Joaquin River (San Joaquin Basin). In

FIGURE 1
Program Study Areas



the south, the remainder of the Westlands Subarea and the Tulare and Kern Subareas drain into the Tulare Basin. The Tulare Basin is generally a closed basin, with outlet to the ocean through the San Joaquin River only in extremely wet years.

- Underlying much of the region is a clay layer (the "Corcoran Clay"), from 20 to 200 feet thick and several hundred feet below the surface. Ground water is found both below the Corcoran Clay and above it. Most irrigation wells draw from below it, and most salinized or contaminated water lies above it. The layer restricts downward water movement, but does not entirely stop it.

Historical Developments

Certain aspects of recent history help to put the drainage problem in context:

- By the 1950's, severe ground-water overdrafting for irrigation led to falling water tables along the west side.

- In the early 1950's, the first Central Valley Project (CVP) water reached the west side via the Federal Delta-Mendota Canal. This water replaced San Joaquin River water that had been used for irrigation on the west side but was now being diverted southward at Friant Dam.

- During the 1960's, new supplies of surface water were delivered through the CVP's San Luis Unit and the State Water Project (SWP) as far south as the Bakersfield area. This additional water was used for irrigation of some new land, but mainly replaced ground-water use. The surface water has replenished the ground-water aquifer and raised the water table. A long-term result, however, has been a slowly developing trend of waterlogging of irrigated lands as water tables have risen to near the land surface. Meanwhile, plans for a master drain to the Delta were not carried out, primarily because of concerns about adverse affects on water quality in the Delta and San Francisco Bay.

- The public law that authorized the San Luis Unit stated that construction would not be commenced until the Secretary of the Interior "has received satisfactory assurance from the State of California that it will make provision for a master drainage outlet and disposal channel for the San Joaquin Valley . . . or has made provision for constructing the San Luis interceptor drain to the Delta designed to meet the drainage requirements of the San Luis unit . . . " In the mid-1970's, the Bureau of Reclamation completed a partial drain for its San Luis Unit, with the drain ending in a series of evaporation ponds at Kesterson Reservoir. In 1983, selenium poisoning of waterbirds at Kesterson was discovered. In March 1985, the Secretary of the Interior ordered the cessation of subsurface drainage discharge to Kesterson Reservoir. By mid-May 1986, all feeder drains leading into the San Luis Drain and Kesterson had been plugged.

- Overall, the water and land development for agriculture has resulted in major losses of native habitats and associated damage to fish and wildlife populations. Subsurface drainage problems have added greatly to these problems.

West-Side Farming

Certain characteristics of irrigated agriculture in the area also help explain the drainage problem:

- More than 90 percent of the 2,470,000 acres classified suitable for irrigation in the study area are irrigated each year.

- About 135,000 acres have subsurface drainage systems.

- Most of the area is irrigated with surface (furrow or border) systems. About one-sixth is sprinkled, and a much smaller amount is drip-irrigated. Sprinklers usually apply water somewhat more efficiently than surface systems. However, there are considerable differences in efficiency among individual irrigation systems. There also are substantial differences in irrigation efficiency from one subarea to the next, and even within subareas.

- The practice of preirrigation (applying water to wet the root zone before the crop is planted) adds substantially to the amount of subsurface drainage water.

- Depending on hydrologic conditions, drainage from upslope lands can increase drainage problems on downslope lands.

- In the five subareas, average irrigation water costs to growers range from $16 to $50 per acre-foot. In some water districts, additional operating and pumping costs increase the total substantially.

Certain institutional issues have important implications for west-side irrigators. Among these are: (1) Water rights, including recent court decisions affecting application of the public-trust doctrine on traditional rights, (2) water and crop subsidies, (3) effects of the Reclamation Reform Act of 1982, and (4) the role of water districts. These issues are the focus of a study now being conducted by the SJVDP.

Environmental Resources

Wildlife--aquatic birds in particular--and fisheries are an important aspect of the valley's drainage problem. Most of the San Joaquin Valley's original lakes, wetlands, and riparian forests have been converted to other uses. Most of those that remain are in the Grassland Water District (in the Grasslands Subarea), where they have been managed to benefit waterfowl and other wetland species. Until recently, about two-thirds of the available water supply to these lands was agricultural drainage. However, drainage water can no longer be used for this purpose because of selenium and other potentially harmful contaminants. Maintenance of the existing wetlands, which are essential to the migratory bird populations of the Pacific Flyway, will require a new, nontoxic water supply.

Native fish in the San Joaquin Valley, such as the chinook salmon, have been largely lost as a result of dams, diversion of riverflows, and degraded water quality.

DRAINAGE AND DRAINAGE-RELATED PROBLEMS

Drainage problems in the valley consists of three separate but related conditions: (1) Shallow ground water, (2) salinity, and (3) selenium and other trace elements. All have implications for water quality, agriculture, fish and wildlife resources, and public health.

Shallow Ground Water

More than one-half of the study area has ground water within 20 feet of the land surface. This acreage has increased dramatically since the 1950's, as a result of rising water tables due to reduction of ground-water pumping after surface water was imported. (See Figure 2.) Problems for growers develop when the water table rises into the crop root zone, generally within 5 feet of the surface (10 feet for deep-rooted orchard crops).

In 1987, the study area contained about 847,000 acres with ground-water levels within 5 feet of the land surface part of the year--an increase from 537,000 acres only 10 years before. If current trends continue, by the year 2000 water tables will be within 5 feet or less of the land surface under 40 percent of all irrigated land in the study area.

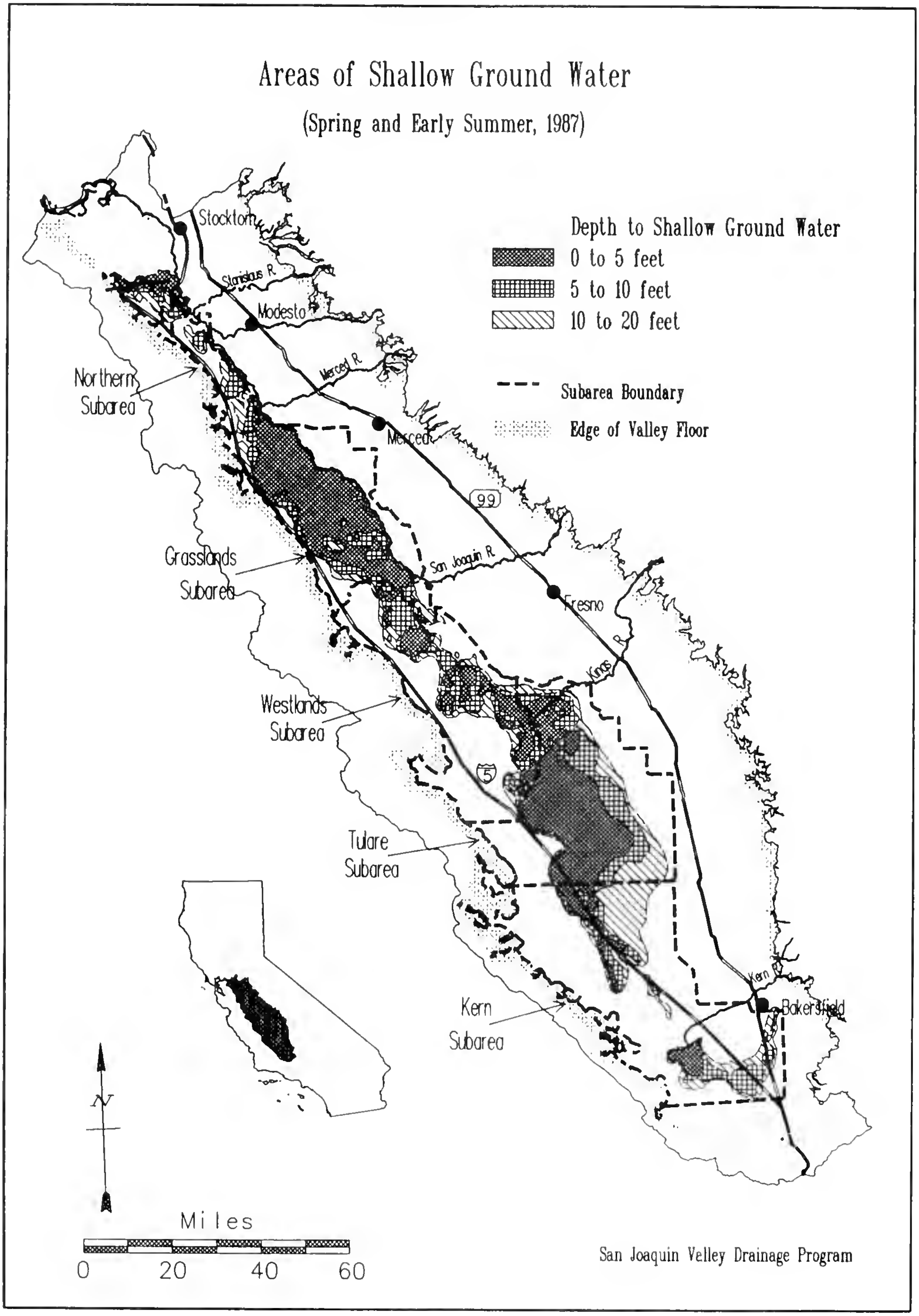
Generally, water tables rise when part of the irrigation water moves below the crop roots. This downward flow is called "deep percolation." Some deep percolation is necessary to leach salts from the root zone. This is the "leaching requirement." A recent study of irrigation performance in 83 west-side fields showed that:

- Unless the entire field is underirrigated, some deep percolation beyond the leaching requirement is inevitable because irrigation water cannot be distributed with complete uniformity.

- The average amount of water applied in the test fields was 2.5 acre-feet per acre per year, and average deep percolation was 0.8 acre-foot. Average irrigation efficiency was calculated at 66 percent. (A high level of irrigation efficiency without underirrigation would be about 80 percent. If that were achieved, deep percolation would be about 0.4 acre-foot per acre per year.)

Water tables continue to rise as long as more water enters a ground water system than leaves it. A computer model being used by the SJVDP shows that the two northern subareas (Northern and Grasslands) have reached hydrologic balance, so existing high water-table problems there are not likely to worsen. But if current trends continue, water tables in the Westlands, Tulare, and Kern Subareas will continue to rise until a hydrologic balance is achieved between recharge (through deep percolation) and discharge (primarily through evapotranspiration).

FIGURE 2



Areas of Shallow Ground Water
(Spring and Early Summer, 1987)
Depth to Shallow Ground Water
0 to 5 feet
5 to 10 feet
10 to 20 feet
Subarea Boundary
Edge of Valley Floor
Stockton
Stanislaus R.
Modesto
Merced R.
Merced
99
San Joaquin R.
Fresno
Kings R.
5
Kern R.
Bakersfield
Northern Subarea
Grasslands Subarea
Westlands Subarea
Tulare Subarea
Kern Subarea
N
Miles
0
20
40
60
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Salts in Ground Water

The problem of high water tables is compounded by salinity. Salts are naturally present in valley soils, and also are imported with water from the Delta. Too much salinity damages crops and can be harmful to freshwater aquatic and wetland habitats. Salts can be leached below the crop root zone, but unless a high water-table field is drained, the salts concentrate in the shallow ground water and return to the root zone when the water table rises.

Vegetables, fruits, and nuts are sensitive to salt damage; grains, cotton, and sugar beets are more tolerant. Water with less than 2,000 parts per million (ppm) "total dissolved solids" (TDS) can be used to irrigate most salt-tolerant crops without reducing yields. With special management, crops have been irrigated with water containing as much as 5,000 ppm. Presently, shallow ground water contains higher salt concentrations under about 400,000 acres, largely in the Westlands, Tulare, and Kern Subareas. These waters can be used for irrigation only by blending with freshwater. (Figure 3 shows the salt content of the shallow ground water.)

Reaching a balance between salt entering and leaving a hydrologic system is crucial for sustaining long-term irrigated agriculture. The SJVDP's computer model of the west side shows a net increase of 3.3 million tons of salt each year in the semiconfined ground-water aquifer. Most of this is in the southern three subareas, where salts are steadily building up in ground water, soils, and evaporation ponds. Currently, the San Joaquin River removes some salts from the Grasslands and Northern Subareas, which helps to maintain salt balance in those subareas.

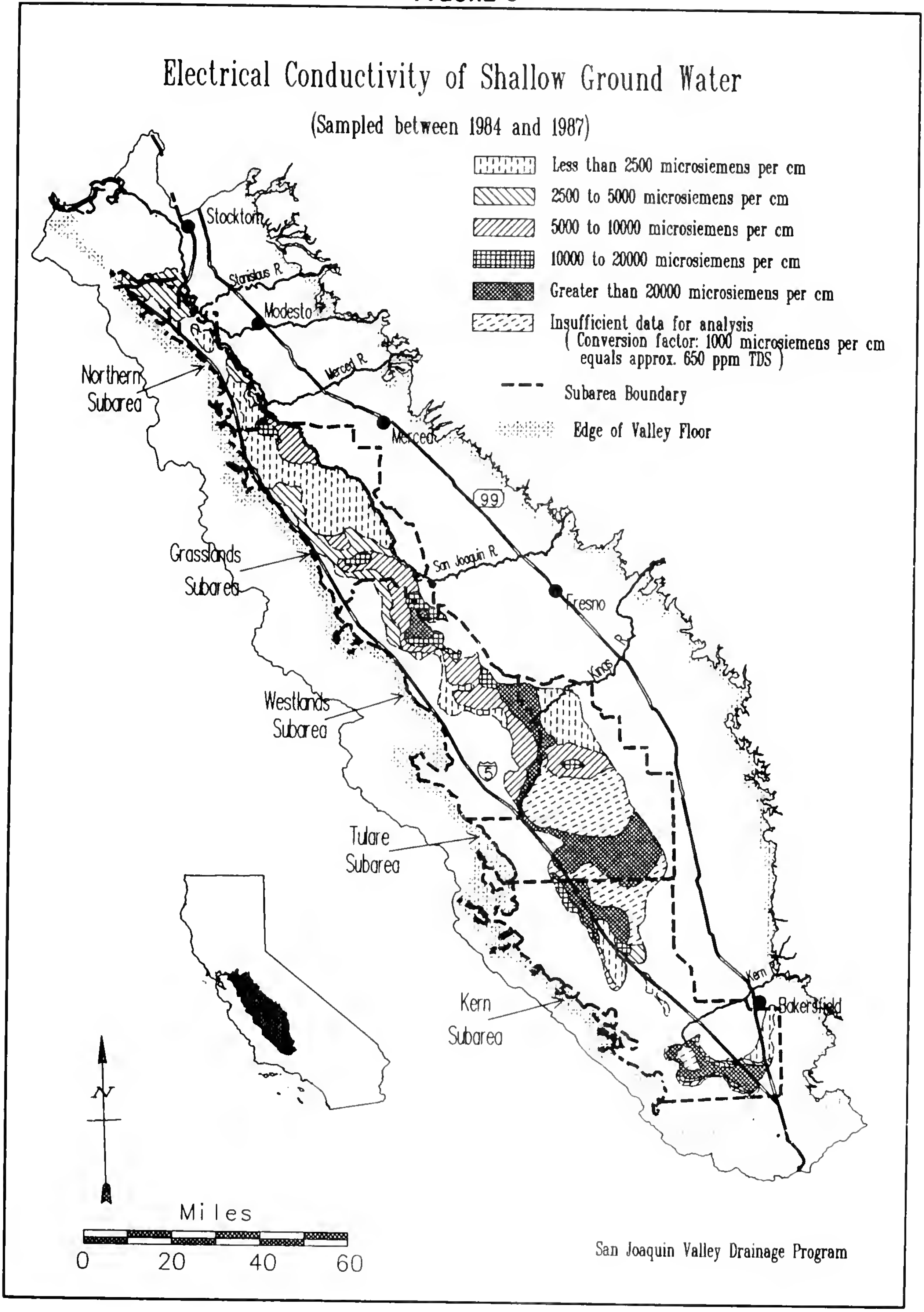
Trace Elements

Toxic and potentially toxic trace elements occur naturally in west-side soils and are leached into the shallow ground water during irrigation. Selenium is considered the chief threat because of its toxicity--to fish, wildlife, and potentially to humans--and because of its wide distribution. Other substances of primary concern are boron, molybdenum, and arsenic. The investigation of the drainage problem has included many other substances, some of which may eventually prove to be of primary concern.

The highest remaining concentrations of selenium in the soil are in more recently irrigated areas lying between alluvial fans (stream-deposited materials from the Coast Ranges) in the Westlands and Kern Subareas. Elsewhere along the west side, decades of irrigation and deep percolation have transferred much of the soluble soil selenium into shallow ground water--where it is distributed along the lower parts of alluvial fans. (See Figure 4.)

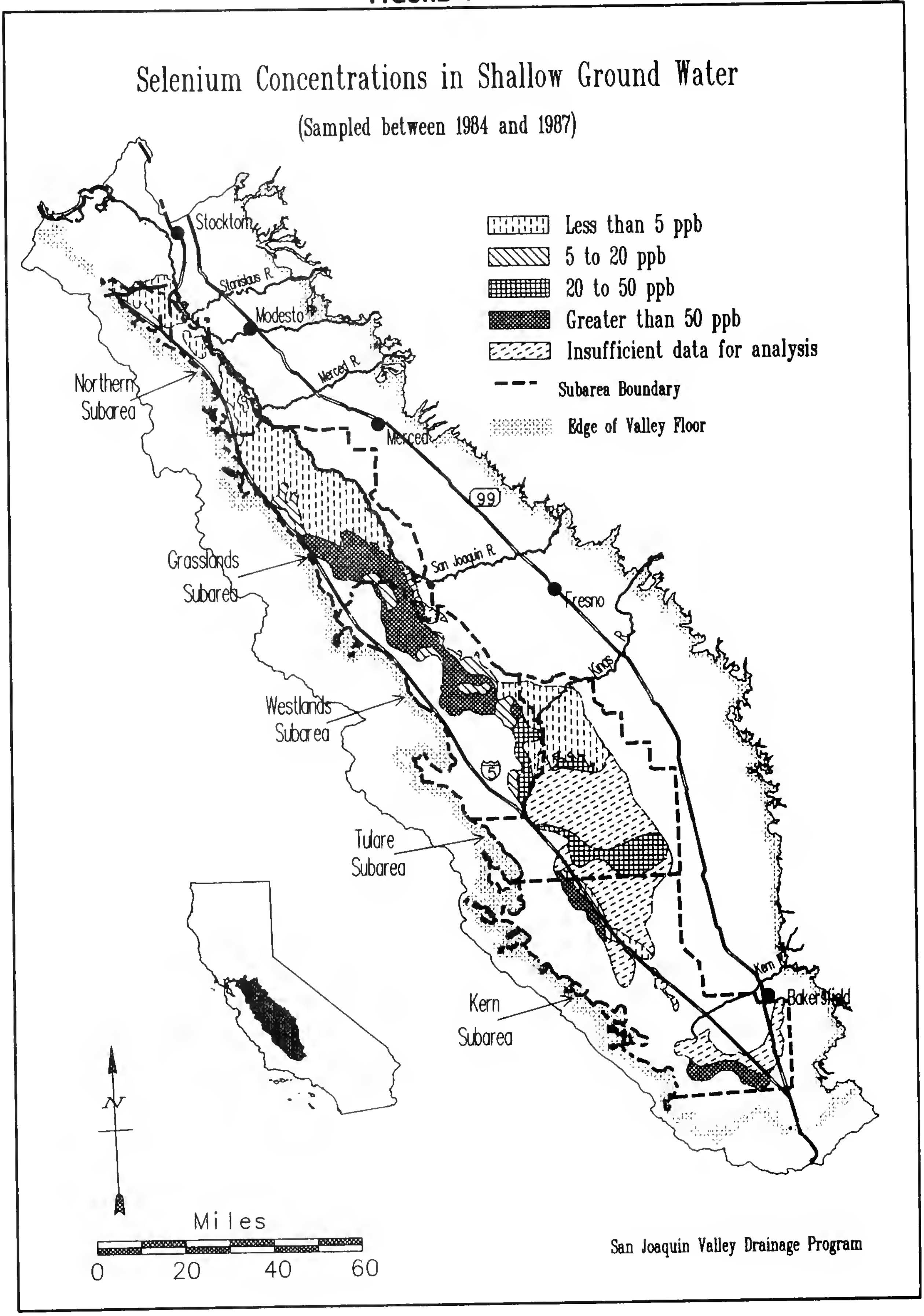
Selenium concentrations tend to be higher in more saline ground water. Where the water table is less than 5 feet below the land surface, selenium, boron, and salts can become increasingly concentrated as crops and evaporation remove the ground water but leave behind most of the minerals.

FIGURE 3



Electrical Conductivity of Shallow Ground Water
(Sampled between 1984 and 1987)
Less than 2500 microsiemens per cm
2500 to 5000 microsiemens per cm
5000 to 10000 microsiemens per cm
10000 to 20000 microsiemens per cm
Greater than 20000 microsiemens per cm
Insufficient data for analysis
(Conversion factor: 1000 microsiemens per cm equals approx. 650 ppm TDS)
Subarea Boundary
Edge of Valley Floor
Stockton
Stanislaus R.
Modesto
Merced R.
Merced
99
San Joaquin R.
Fresno
Kings R.
5
Kern R.
Bakersfield
Northern Subarea
Grasslands Subarea
Westlands Subarea
Tulare Subarea
Kern Subarea
N
Miles
0
20
40
60
San Joaquin Valley Drainage Program

FIGURE 4


Selenium Concentrations in Shallow Ground Water
(Sampled between 1984 and 1987)
Less than 5 ppb
5 to 20 ppb
20 to 50 ppb
Greater than 50 ppb
Insufficient data for analysis
Subarea Boundary
Edge of Valley Floor
Stockton
Stanislaus R.
Modesto
Merced R.
Merced
99
San Joaquin R.
Fresno
Kings R.
Kern R.
Bakersfield
5
Northern Subarea
Grasslands Subarea
Westlands Subarea
Tulare Subarea
Kern Subarea
N
Miles
0
20
40
60
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The SJVDP also has studied selenium in the San Joaquin River. During the irrigation season, agricultural drainage water provides almost the entire flow of the middle portion of the river. Most selenium entering the river is dissolved in drainage water that is transported primarily through Salt and Mud Sloughs. Water in the San Joaquin River downstream from those sloughs exceeds State-proposed selenium water-quality objectives for protection of aquatic life (5 parts per billion) more than 40 percent of the time.

The SJVDP has surveyed other trace elements in soils and ground water, finding:

- o Elevated concentrations of boron in parts of all subareas except the Northern Subarea.

- o Elevated concentrations of arsenic and molybdenum in old lakebeds in the Tulare and Kern Subareas.

Trace elements, including selenium, also are found in evaporation ponds--sometimes in very high concentrations. There are about 7,500 acres of evaporation ponds in the San Joaquin Valley, primarily in the Tulare and Kern Subareas. No other method for disposing of very saline drainage is currently available in those areas.

Evaporation ponds attract large numbers of aquatic birds and provide wintering and nesting habitats. Adverse effects of selenium on embryos and young birds have been documented at several ponds. Evaporation ponds are the greatest threat to aquatic birds of any drainage-related facilities in the valley.

Humans are most likely to contact agricultural drainage-water contaminants through a variety of indirect means (for example, consumption of contaminated fish or wildlife, wild or cultivated plants, or livestock; consumption of or skin exposure to contaminated soils or sediments; and inhalation of contaminated air).

Studies throughout the western San Joaquin Valley have shown that certain types of fish and wildlife have accumulated sufficient levels of selenium that advisories have been issued by the State to restrict consumption of these plants and animals. Preliminary research on a small number of samples from the area has indicated that cultivated plants and domestic livestock do not contain excessive selenium concentrations; however, other substances of concern have not, as yet, been measured. Early health surveys of population groups considered at risk for overexposure to selenium (Kesterson Reservoir workers and a small foraging population) have not shown evidence of selenium toxicity; however, other groups that may be at risk (for example, hunters and fishermen, or subsistence gardeners in contaminated areas) have not been evaluated. The degree to which the public adheres to health advisories is not known. Qualitative risk assessments for public exposure to other drainage-water contaminants currently are under preparation. In the interim, a number of actions have been recommended to reduce potential public health risks.

POSSIBLE OPTIONS

The following list of drainage management options is summarized from Chapter 3 of the report. Some of these options already are in use, some are in the experimental stage, and some are untested. Some are technological in nature, some would offer economic incentives, some are management-oriented, and some are institutional.

No single option is likely to solve a major part of the valley's drainage problems. What will solve the drainage problem, it is hoped, are certain combinations of options that are proposed as alternative plans for each subarea. One such set of alternative plans, utilizing available technologies, is described in a following section of this summary.

There are many possible in-valley approaches to managing the valley's drainage problems. Most of them are workable only in combination with others. No single one applies to every problem site.

The options fall into seven categories:

- Source control to reduce drainage from individual farms.
- Management of shallow water tables by pumping.
- Drainage-water treatment.
- Drainage-water reuse.
- Drainage-water disposal in the valley.
- Fish and wildlife measures.
- Institutional changes.

Source Control

There are four approaches to drainage source control on the farm: (1) Water conservation, (2) drainage management, (3) crop management, and (4) alternate land use.

Water conservation options include:

- Use better irrigation methods such as shorter furrow lengths, recycled tailwater, and sprinkler, drip, or improved furrow systems.
- Improve scheduling of irrigation, making use of available data on root-zone storage capacity and crop water use rates.
- Improve irrigation management.
- Deliver irrigation water more promptly on demand by providing more conveyance capacity where necessary, more conjunctive use of surface and ground water, and more coordination of water delivery systems.

- Intercept or reduce seepage from canals, ditches, and natural channels.

- Adapt tillage practices to distribute water more uniformly and reduce deep percolation.

Drainage management options include:

- Separate surface and subsurface drainage, so waters of different quality can be managed more efficiently.

- Recycle tailwater from surface irrigation systems.

- Regulate water tables by controlling tile-drain flows in order to make more shallow ground water available for crop use.

- Space tile drains closer together in order to intercept only the better quality ground water that lies closer to the surface.

Crop management options include:

- Grow crops that tolerate salts, high water table, or drought, in order to reduce the need for drainage.

- In areas with highly contaminated soils or ground water, grow nonirrigated crops with minimal water requirements.

- Grow crops that accumulate or volatilize selenium.

Alternate land use options include:

- Cease irrigating "hot spots" of selenium by purchasing the land or by using economic incentives. Another possibility is to reclassify land within the CVP as "nonirrigable."

- Convert irrigated lands to upland wildlife habitat.

- Convert irrigated lands to wetland habitat.

<u>Ground-Water Management</u>

In addition to individual farm source control, ground-water management could be implemented by districts or regions. This would mean increasing the pumping of ground water over substantial areas in order to lower the shallow water table. These options include:

- Pumping more water from below the Corcoran Clay. Increased pumping from below the clay could alleviate, indirectly, the water-table problem near the surface by causing the shallow ground water to lower as water would move toward well-column inlets (hundreds of feet below the surface). A gradual deterioration of water quality in the deep aquifer and land subsidence would likely accompany large-scale pumping.

- Pumping from the Sierran sands along the eastern side of the study area. Pumping from depths of 30 to 250 feet below the land surface could also lower water tables and provide a low-selenium, although somewhat saline, supplemental water supply.

- Pumping from Coast Range alluvium along the west side of the study area. An SJVDP model suggests that regional-scale pumping at 200 to 300 feet could lower water tables as effectively as tile drains. Water presently below 150 feet is moderately saline, but is likely to contain little selenium. However, with long-term pumping, selenium-contaminated shallow ground water would likely move downward.

- Pumping shallow water. In the Northern Subarea, shallow, saline ground water might be pumped into the San Joaquin River during high flows, leaving more room in the aquifer for deep percolation during the irrigation season.

Reliable site-specific forecasts of the probable effects of ground-water management options will depend on results of additional investigations.

Drainage-Water Treatment

Various studies have been and are being conducted to identify affordable methods of removing trace elements (primarily selenium) from drainage water. Most of these options are still in the laboratory test stage. A few are somewhat more advanced, but additional work with pilot prototype plants is needed to test performance and to estimate costs.

There are no immediate prospects for an economically feasible way to remove selenium, or boron and salts, from drainage water, but such a process is badly needed--if only to deal with concentrated selenium residues in evaporation ponds.

Potential treatment processes include:

- Five biological methods: anaerobic-bacterial, facultative-bacterial, microalgal-bacterial, microbial volatilization in evaporation ponds, and microbial volatilization from soils and sediments.

- Six physical-chemical methods: geochemical immobilization, adsorption using iron filings, adsorption using iron oxides, ion exchange, reverse osmosis, and cogeneration to produce electricity plus heat for desalinization.

Drainage-Water Reuse

Where there are no disposal outlets, saline drainage water is commonly mixed with freshwater for reuse in irrigation. This practice can result in the buildup of salt in soil and shallow ground water and eventually damage crops. One suggested strategy is to use freshwater to establish young plants, and then to irrigate the crop with drainage water--making sure that the root zone is well drained.

Subsurface drainage water containing salinity (TDS) of up to 3,000 ppm has been used to grow salt-tolerant commercial crops. Eucalyptus trees for firewood or wood pulp and saltbush for forage can be irrigated with even more saline water--if salts are leached from the root zone.

Plantings of eucalyptus and saltbush also could benefit wildlife, assuming (from preliminary studies) that the buildup of toxic trace elements does not cause problems.

Other potential options for reuse of drainage water:

- Use it to cool fossil-fueled powerplants. Costly water treatment would be required. Also, there are no plans to locate new powerplants in the valley, and existing plants have cooling water supplies.

- Use it in solar ponds to produce electrical energy. This process has been demonstrated on a small scale, but cannot compete economically with conventional powerplants unless fuel oil prices again rise to about $30 per barrel.

- Recover salts from evaporation ponds for industrial use. Much more refining might be required. Even an unprofitable operation, however, might be justified as part of a drainage disposal system.

- Use drainage water in aquaculture. The possibility of trace-element concentration would have to be considered in determining the marketability of any organisms grown in drainage water.

Drainage-Water Disposal

Several options for drainage disposal depend on using the San Joaquin River. Drainage from the Northern and Grasslands Subareas currently goes into the river. In the future, the availability of the river will depend on the salinity water-quality objectives set for the river. It is estimated that most of the Northern Subarea and almost half of the Grasslands Subarea could be drained directly into the river and still meet the objectives.

Other potential options involving the San Joaquin River:

- Use freshwater to dilute drainage water going into the river (particularly in the Northern Subarea). The cost would be prohibitive if selenium concentrations are above 50 ppb. (Under current law, dilution is not a beneficial use of freshwater.)

- Clean and use part of the San Luis Drain north of the Mendota Pool to convey freshwater to the Grasslands area. The northern part of the drain would be used to convey drainage water around the Grasslands area and through sloughs to the river.

Other options for drainage disposal are:

- Evaporate drainage water in ponds, currently a common practice in the southern valley. Ponds are regulated by the State through the issuing of waste discharge permits, which now must be accompanied by an agreement between the owner or operator and the California Department of Fish and Game that wildlife will be protected. Starting in 1989, regulatory agencies will work toward developing mitigation actions to offset unavoidable effects of pond operation. It is likely that the problems of selenium toxicity will cause the costs and operation of most ponds to rise sharply as regulations require, in effect, that ponds be bird-free or bird-safe.

- Clean and use the San Luis Drain south of the Mendota Pool to convey drainage water for treatment and disposal within the Westlands Subarea.

- Transport drainage water to the western edge of the valley and use it to irrigate eucalyptus trees and/or saltbush over a present ground-water table depression.

- Inject drainage water into saline ground water below the freshwater zone, 3,000 to 3,500 feet down.

- Inject drainage water into very deep (7,000 feet or more) saline geological formations. A deep-well injection testing program is being conducted near Mendota.

- Transport some drainage water (30,000 to 60,000 acre-feet yearly) to the east side of the valley. Irrigation water soil-infiltration problems on the east side of the valley are caused by water supplies low in salt and relatively high in sodium; also, forage crops there are generally selenium-deficient. The overall chemical effects of imported drainage water would have to be considered.

Fish and Wildlife Measures

Fish and wildlife objectives include: (1) Protection of populations, (2) restoration of habitat, (3) provision of substitute water supplies, and (4) improvement of the resources.

Options for protection of fish and wildlife include:

- More aggressive implementation/enforcement of amendments to existing laws, or passage of new laws addressing: planning, environmental assessment, and mitigation.

- Regulation of take of fish and wildlife.

- Regulation of land and water uses.

- Regulation of water quality.

Options for restoration of drainage-contaminated fish and wildlife habitats include:

- Flooding and flushing with freshwater.
- Soil and vegetation management.
- Cultivation and harvesting of selenium-accumulating plants.
- Microbial volatilization.
- Geochemical immobilization.
- Sequential implementation of decontamination and restoration.

Options for providing wildlife areas with nontoxic freshwater supplies to substitute for drainage water previously used include:

- Reuse of drainage water.
- Reallocation of freshwater supplies.
- Altered sequence of water delivery.
- Modifications to existing or proposed water-storage projects and delivery systems.
- Wetlands water storage.

Options for improving the status of the valley's fish and wildlife resources beyond protection, restoration, and substitute water-supply levels include:

- Agroforestry.
- Management, development, reclamation, and acquisition of fish and wildlife habitats and associated public-use facilities.
- Uncontaminated evaporation ponds/wetlands.

Institutional Changes

The SJVDP study includes a number of possible changes in laws, policies, and practices in order to help solve drainage problems and to protect fish and wildlife resources. Many of these options provide economic and other incentives for growers to conserve irrigation water and/or reduce the production of agricultural drainage water. The institutions involved include local, regional, State, and Federal water agencies and others.

These options are:

- Raise the price of water through water supply contracts. This would require renegotiation of contracts, and a fundamental shift in Federal and State policies. Preliminary analyses indicate that significant price increases would be needed to motivate growers to change irrigation methods and management.

- Charge higher water rates at the district level, with excess funds rebated or applied to drainage management programs.

- Modify or eliminate irrigation subsidies, including those on Federal and, possibly, State water supplies.

- Allow water districts (and growers) to pay only for water actually used and to receive credit for unused water.

- Use tiered water pricing. This means that per-unit prices increase as subsequent "blocks" of water are used by a grower during a season. Tiered pricing of Federal and State project water would require changes in Federal and State law and/or policy.

- Make it easier to: (1) Trade water, which would increase the value of transfers and thereby encourage conservation, or (2) market water, which, besides encouraging conservation, might eliminate irrigation on lands with severe drainage problems.

- Rebate taxes based on total water management efficiency measured by reduction in subsurface drainage water produced.

- Provide income tax credits for investments in water conservation.

- Authorize use of Federal and State water to dilute agricultural drainage water so the water could meet discharge standards of, for example, the San Joaquin River.

- Impose drainage-effluent fees on growers and/or water districts, in proportion to the amount and quality of drainage water.

- Limit the amount of very poor-quality drainage water discharged from farms, districts, or regions.

- Allow growers to trade permits for off-farm discharge of limited amounts of drainage-water constituents (e.g., selenium, boron, or salts).

- Form a regional drainage district to address drainage and drainage-related problems more effectively and economically. Members could be either water districts or individual growers.

- Increase subsidies on Federal and State project water going to private and public wetlands, in order to improve wildlife habitats.

- Authorize CVP and SWP water for environmental and other uses before agriculture.

- Reallocate water from agriculture to fish and wildlife uses. This would probably require agency agreements and perhaps legislative action. One way to save water for reallocation to fish and wildlife would be to reduce irrigation demand through increased conservation or land retirement. Another would be to redefine "beneficial use" of water to exclude: (1) Production of highly contaminated drainage, or (2) irrigation in excess of crop water use plus leaching.

- Reauthorize the Federal and State Water Projects to give equal consideration to water needs of fish and wildlife.

ALTERNATIVE PLANS

Certain options from the preceding list have been combined into preliminary alternative plans that emphasize what might be done between now and the year 2000 to address the drainage problem using "available technology." An alternative plan has been developed for each subarea, tailored to water-quality zones. (Within each subarea, drainage problem land is divided into several water-quality zones.)

Additional alternative plans emphasizing other themes--such as ground-water management, drainage-water treatment, and land retirement--are being formulated. The SJVDP's final report will present a number of possible plans, including recommendations for action. These plans will reflect information obtained from upcoming public meetings and from research and special studies on: (1) Geohydrology, (2) quality of ground water in the Tulare and Kern Subareas, (3) deep-well injection for drainage disposal, (4) treatment of drainage water to remove selenium and other toxics, (5) agricultural economics, and (6) advantages and disadvantages of various possible institutional changes.

The alternative plans presented in this report include only options of currently available technology. These preliminary plans share a common strategy:

- First, through water conservation, substantially reduce the amount of drainage water produced through irrigation.
- Then, use the drainage water collected to grow salt-tolerant plants, which will evapotranspire much of the water and concentrate the dissolved minerals.
- Finally, store the remaining volume of saline water underground or in small evaporation ponds (to be managed as bird-safe or bird-free disposal sites).
- Also, in some subareas, some drainage water would go into the San Joaquin River, to the extent that the river can assimilate it while meeting water-quality objectives.
- Irrigation water made available through on-farm water conservation, pumping of ground water, and growing of salt-tolerant crops would be allocated to wetlands and rivers, to increase protection of fish and wildlife, to help decontaminate and restore habitat, and to provide substitute water supplies.

The No-Action Scenario

Before discussing alternative plans, it is appropriate to ask: What if there were no plans? What if no coordinated, comprehensive public and private action is taken to solve the valley's drainage problem?

Assuming that existing trends generally continue in the agricultural economy, in environmental protection activities, in governmental spending, and in water development and use, and also assuming no drainage outlet from the valley, then such a future without a coordinated, comprehensive plan to deal with drainage water very likely would result in:

- o Even more acreage with high water tables and even more saline ground water, both conditions leading to substantial loss of farmland.

- o Increasing public pressure for environmental protection, resulting in existing valley wetlands and wildlife areas being preserved and protected, but no new areas or water supplies being developed for these needs.

- o Uncoordinated actions by various individuals and groups, leading to litigation not only between agricultural and environmental interests, but among similar user and interest groups.

- o Piecemeal legislation and institutional changes, leading to fewer choices and greater costs for almost everybody involved.

Preliminary Alternative Plans

The SJVDP's first set of alternative plans is designed to use available technology to eliminate or dispose of "problem water." Problem water is ground water within 5 feet of the surface of irrigated lands during at least part of the year, and which generally has chemical characteristics that adversely affect agriculture--and if drained, fish and wildlife, public health, or attainment of State water-quality objectives. In developing these plans, the first step was to divide each subarea into zones based on shallow ground-water quality, and then forecast the yearly volume of problem water expected in that zone by the year 2000.

The next step was to outline a procedure to reduce the production of drainage water as much as possible (source control) and then concentrate the remaining problem water so that only a small amount would have to be stored or disposed of. To do this, it is assumed that:

- o Growers would improve irrigation efficiency to reduce deep percolation, using better irrigation management and scheduling and such technologies as shorter furrow lengths and tailwater return systems. These on-farm techniques should reduce drainage-water production by 40 to 50 percent in most zones.

- o In certain areas, some drainage water would go into the San Joaquin River (where permitted by State water-quality objectives).

- o Some of the remaining problem water could be used to irrigate salt-tolerant crops such as cotton and grain. Drainage from those crops would be applied to plantings of eucalyptus trees; in turn, drainage from the eucalyptus trees would be partially consumed by plantings of saltbush.

- The remaining highly concentrated drainage water would be disposed of in two ways: (1) In evaporation ponds made bird-safe or bird-free, or (2) by pumping deep ground water from below the saltbush, thereby lowering the water table in that locality to permit storage of saline drainage water in the shallow aquifer.

Finally, a preliminary estimate was made of costs for the alternative plan. These costs will be compared with the costs of other alternatives now being developed. Detailed economic analyses of both direct and indirect benefits, costs, and impacts will be made.

The ways in which options are combined and the extent to which they are used vary by subarea and by water-quality zone. Each subarea alternative plan reflects the water-quality, environmental, and agricultural conditions in that subarea.

Overall Impacts

How much problem water would be dealt with in each step of the process? Here are overall estimates for the Grasslands, Westlands, Tulare, and Kern Subareas, where the amount of problem water in the year 2000 is forecast to total 307,500 acre-feet yearly from 409,000 acres of land.

Acre-feet of problem water reduced yearly by improved irrigation management	128,800
Discharged to the San Joaquin River	35,000
Removed by reuse on eucalyptus trees and saltbush	120,200
Stored in ground water	11,400
Stored in evaporation ponds	12,100
TOTAL	307,500

What effects would the proposed plans have on land and water use? How much would they cost? Here are total estimates for the four subareas:

Cropland converted to eucalyptus groves and saltbush fields	28,200 acres
Irrigation water saved, mostly by reduced deep percolation (this alternative includes hypothetical allocation of this water for fish and wildlife purposes)	200,000 acre-feet
Total costs per year	$29.4 million
Yearly cost per acre-foot of problem water	$96
Yearly cost per acre of land with drainage	$72

What environmental effects--on the San Joaquin River, and on fish and wildlife, for example--could be expected? What about public health?

All drainage water from the Northern Subarea and about 60 percent of the drainage water from the Grasslands Subarea, because of its relatively good quality, could be assimilated safely by the river. Discharge of the remaining Grasslands drainage water would not be acceptable, because the selenium-assimilating capacity of the river would be exceeded.

Elsewhere on the west side, storage of highly concentrated drainage--even in relatively small amounts--would require special precautions. Aquatic birds would have to be kept out of most evaporation ponds; adjacent wetland areas to attract the birds might be required. Storage of concentrated drainage in shallow aquifers would, over time, degrade the ground-water resource. Wildlife in eucalyptus groves and saltbush fields would have to be monitored for harmful effects.

Public health concerns involve hunters, fishermen, and foragers in high-selenium locations. Actions to inform these users of potential public health problems and preclude their access to toxic evaporation ponds are a part of this alternative.

Impacts on Subareas

Throughout the study area, the alternative plans developed so far for water-quality zones reflect local conditions. Here, briefly summarized from the individual zone plans, are the preliminary alternative plans for the five subareas. (Drainage volume reductions for the subareas are also summarized in Table 1 [page 24]. Table 2 [page 25] summarizes major direct effects of the alternatives by water-quality zone.)

Northern Subarea. Because drainage problems in this far northern end of the study area are relatively minor, no alternative plan is presented under the theme of available technologies.

Grasslands Subarea. Annual volume of problem water in the year 2000: 86,000 acre-feet from 116,000 tile-drained acres.

Planned procedure for reducing the volume of problem water:

- On-farm source control: 27,200 acre-feet.
- In areas free of selenium, all subsurface drainage water would be discharged into the San Joaquin River: 22,000 acre-feet.
- Discharge of drainage with selenium to San Joaquin River (within the river's selenium-assimilative capacity): 13,000 acre-feet.
- Drainage-water reuse on eucalyptus and saltbush: 21,900 acre-feet.

- Pumping from below saltbush plantings to create storage space in the aquifer for drainage of water from the saltbush: 1,700 acre-feet.
- Evaporation ponds: 200 acre-feet.
- Estimated cost: $63/acre-foot of drainage water, or $47/acre of contributing land.

Proposed actions to protect and/or restore public health and fish and wildlife:

- Public warnings about hunting, fishing, and food-gathering in areas where selenium concentrations are high.
- Nontoxic freshwater supplies (conserved from agricultural irrigation) for existing wetlands and wildlife areas (129,000 acre-feet/year) and instream flows in the Merced River (20,000 acre-feet/year).

Westlands Subarea. Annual volume of problem water in the year 2000: 84,000 acre-feet from 108,000 tile-drained acres.

Planned procedure for dealing with problem water:

- On-farm source control: 37,900 acre-feet.
- Drainage-water reuse on eucalyptus and saltbush: 40,400 acre-feet.
- Pumping from below saltbush plantings to create storage space in the aquifer for drainage of water from the saltbush: 5,300 acre-feet.
- Evaporation ponds: 400 acre-feet.
- Estimated cost: $103/acre-foot of drainage water, or $77/acre of contributing land.

Proposed actions to protect and/or restore public health and fish and wildlife:

- Public warnings about waterfowl hunting in high-selenium localities.
- Hazing or other methods to reduce harm to aquatic birds at toxic evaporation ponds.

Tulare Subarea. Annual volume of problem water in the year 2000: 92,000 acre-feet from 126,000 tile-drained acres.

Planned procedure for dealing with problem water:

- On-farm source control: 42,700 acre-feet.
- Drainage-water reuse on eucalyptus and saltbush: 41,100 acre-feet.

- o Pumping from below saltbush plantings to create storage space in the aquifer for drainage of water from the saltbush: 300 acre-feet.

- o Evaporation ponds: 7,900 acre-feet.

- o Estimated cost: $115/acre-foot of drainage water, or $86/acre of contributing land.

Proposed actions to protect and/or restore public health and fish and wildlife:

- o Public warnings about waterfowl hunting at evaporation ponds.

- o Nontoxic freshwater supplies (conserved from agricultural irrigation) for existing wetlands and wildlife areas (9,700 acre-feet/year).

- o Hazing or other methods to reduce harm to aquatic birds at toxic evaporation ponds.

<u>Kern Subarea</u>. Annual volume of problem water in the year 2000: 45,500 acre-feet from 60,000 tile-drained acres.

Planned procedure for dealing with problem water:

- o On-farm source control: 21,000 acre-feet.

- o Drainage-water reuse on eucalyptus and saltbush: 16,800 acre-feet.

- o Pumping from below saltbush plantings to create storage space in the aquifer for drainage of water from the saltbush: 4,100 acre-feet.

- o Evaporation ponds: 3,600 acre-feet. (All but 200 acre-feet would go to already existing ponds.)

- o Estimated cost: $105/acre-foot of drainage water, or $79/acre of contributing land.

Proposed actions to protect and/or restore public health and fish and wildlife:

- o Public warnings about waterfowl hunting near evaporation ponds.

- o Nontoxic freshwater supplies (conserved from agricultural irrigation) for existing wetlands and wildlife areas (38,000 acre-feet/year).

- o Hazing or other methods to reduce harm to aquatic birds at toxic evaporation ponds.

TABLE 1

SUMMARY OF DRAINAGE VOLUME REDUCTION
AVAILABLE TECHNOLOGIES ALTERNATIVE
(acre-feet)

(Estimated volume of Problem Water to be managed by Year 2000 = 307,500 acre-feet)

SUBAREA	REDUCTION OR DISPOSAL METHOD					TOTAL
	IRRIGATION IMPROVEMENTS	DISCHARGE TO SAN JOAQUIN RIVER	EUCALYPTUS AND SALTBUSH PROPAGATION (REUSE)	GROUND-WATER STORAGE	EVAP POND DISPOSAL	
GRASSLANDS	27,200	35,000	21,900	1,700	200	86,000
WESTLANDS	37,900	0	40,400	5,300	400	84,000
TULARE	42,700	0	41,100	300	7,900	92,000
KERN	21,000	0	16,800	4,100	3,600	45,500
TOTAL	128,800	35,000	120,200 (a)	11,400	12,100	307,500

(a) Includes about 20,000 acre-ft reduction in deep percolation, due to replacement of conventional crops with special crops such as eucalyptus trees (assumes no freshwater supply).

TABLE 2

MAJOR DIRECT EFFECTS
AVAILABLE TECHNOLOGIES ALTERNATIVE

SUBAREA	WATER QUALITY ZONE	IRRIGATED LAND AREA REDUCTION (acres)	AGRICULTURAL WATER REQUIREMENT REDUCTION (acre-feet/year)	TOTAL ANNUAL COST ($1,000)	SUPPLEMENTAL FISH & WILDLIFE WATER SUPPLIES (acre-feet/year)
GRASSLANDS	A	3,600	38,400	4,642	
	B	800	5,500	769	
	C	0	0	0	
	Subtotal	4,400	43,900	5,411	149,000 (a)
WESTLANDS	A	2,300	17,700	2,425	
	B	1,900	14,800	1,500	
	C	3,600	27,200	3,760	
	D	800	6,700	955	
	Subtotal	8,600	66,400	8,640	0
TULARE	B	3,100	16,700	2,879	
	C	300	3,000	390	
	D	700	4,900	717	
	E	2,050	13,900	2,342	
	F	3,800	24,400	4,270	
	Subtotal	9,950	62,900	10,598	9,700 (b)
KERN	A	2,100	14,300	2,085	
	B	200	1,600	154	
	C	350	2,400	359	
	D	2,600	21,600	2,176	
	Subtotal	5,250	39,900	4,774	38,000 (b)
TOTAL		28,200	213,100 (c)	29,423	196,700

(a) Includes 20,000 acre-feet of anadromous fish flows down the Merced River and 129,000 acre-feet of substitute wetland-wildlife habitat water supplies.
(b) Alternative habitat water supply associated with hazing of evaporation ponds.
(c) Reduction includes 128,800 acre-feet due to improved irrigation and drainage management practices, 72,900 acre-feet due to reduction in irrigated agricultural lands (used to grow eucalyptus trees and saltbush), and 11,400 acre-feet due to increased ground-water pumping to control shallow water depth.

ACTIVITIES AND SCHEDULE FOR PROGRAM COMPLETION

A range of alternatives for the planning subareas are being formulated and evaluated. Opportunities are being provided for the general public, special-interest groups, and governmental agencies to play important roles in this formulation and evaluation process. Comments are being solicited and utilized throughout the planning process, which will culminate in the recommendation of subarea plans and/or a comprehensive plan for the west side of the valley.

The SJVDP also is completing technical studies and other work that fall into two primary areas: (1) Special studies to provide specific information critical to plan formulation and evaluation, and (2) improving the analytic tools used in evaluating options and planning alternatives. Studies are being completed in 1989 and early 1990 on specific aspects of:

- Geohydrology.
- Public health.
- Fish and wildlife resources.
- Treatment technology.
- Institutional studies.
- Social analysis.

Work to improve evaluative tools centers around the SJVDP's computerized Westside Agricultural Drainage Economics model. The model covers the principal study area and defines relationships between economic, ground-water and salinity, and agricultural production parameters. It will be used to help estimate the effects of one parameter on another in individual alternative plans.

The ongoing work to improve the information base and analytic tools is being done in support of formulation and evaluation of alternative plans to solve valley drainage and drainage-related problems. Major activities and milestones leading to completion and recommendation of plans include:

- A series of public meetings in fall 1989 to review the options and preliminary alternatives presented in this interim report and to discuss possible additional alternatives.
- Completion in mid-1990 of a draft report presenting a range of alternative plans.
- Public review of the draft report.
- Completion of a final report by October 1990.

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